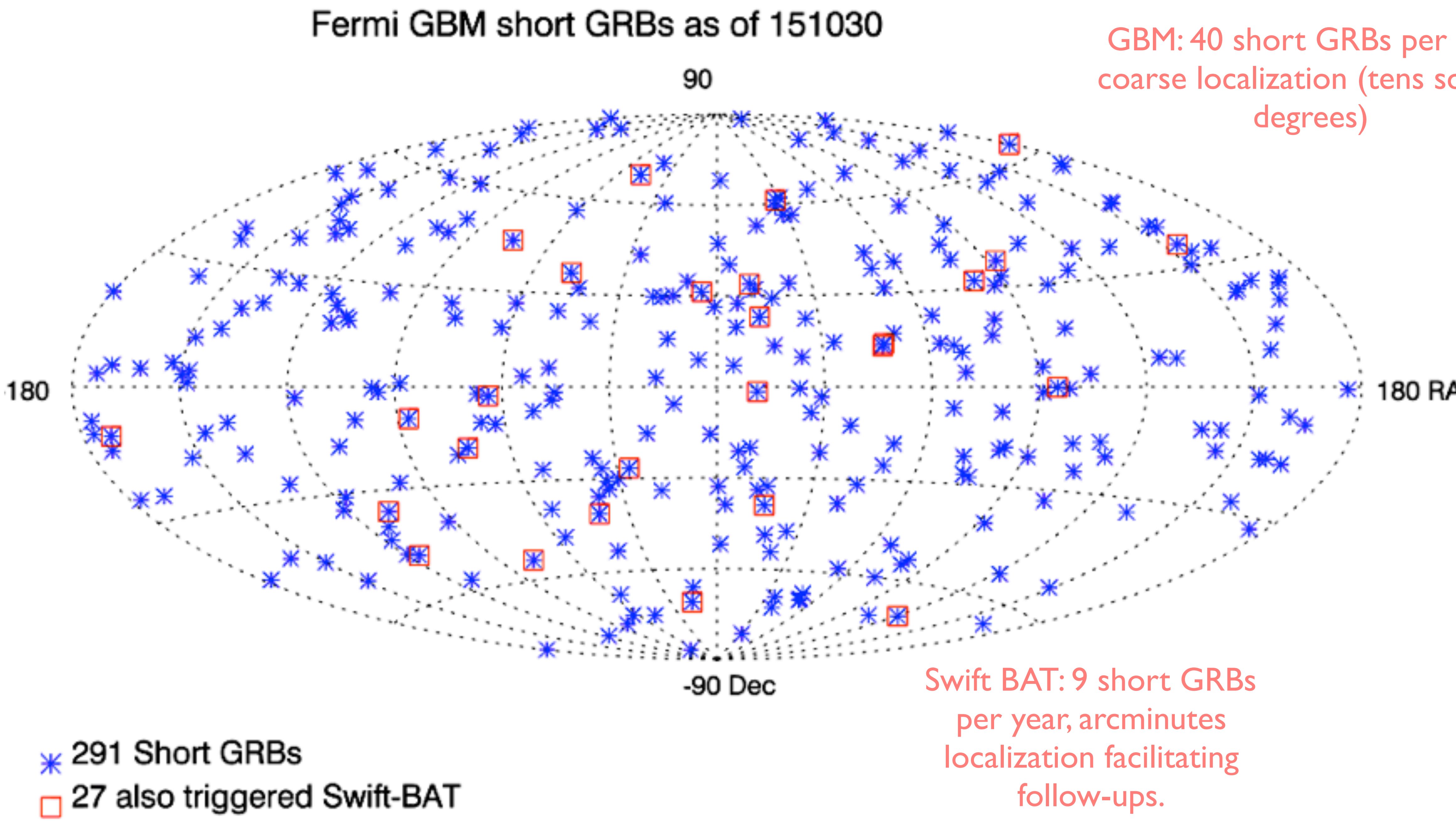
Finding Fermi GBM Counterparts to LIGO Gravitational-Wave Candidates

Valerie Connaughton

Universities Space Research Association
Huntsville, AL

for the GBM team and the GBM-LIGO electromagnetic follow-up group

Owing to all-sky coverage, Fermi GBM detects and localizes more short GRBs than other GRB detectors.



GBM: 40 short GRBs per year, coarse localization (tens square degrees)

Swift BAT: 9 short GRBs per year, arcminutes localization facilitating follow-ups.

Fermi GBM and Swift BAT detect the same population of short GRBs: we shall assume they all come from mergers of binary neutron star systems (could also be neutron star - black hole).

- Swift BAT does not see a separate class of collapsar short GRBs that dominate the long-duration end of the short GRB population.
- Swift BAT sees some weaker GRBs close to its fully-coded center but its sensitivity drops off faster towards the edge than it does for long GRBs.
- Fermi GBM short GRB sensitivity is more even over its field-of-view.
- These effects are a wash and GBM and BAT have short GRB detection rates that reflect their fields-of-view.
- See poster xx by Eric Burns for study of short GRBs detected/not detected by Swift BAT/GBM, and arXiv.xxxx

Most of the Swift BAT short GRBS that did not trigger GBM are found in a ground search of the Continuous Time-Tagged Event (CTTE) data for untriggered bursts.

Missed GRBs are either weak (detected close to BAT's boresight) or at large offset to Fermi boresight.

Missed GRBs are not systematically long i.e. collapsars masquerading as mergers

	BAT					GBM		
GRB (Name)	T_{90} (sec)	Fluence (%ile)	Peak Flux (%ile)	PL Index	Partial Coding	LAT offset (degrees)	# of NaI detectors	Ground (signal)
140606A	0.34	34.1	6.7	0.53	86	91	3 (18, 49)	Strong
120403A	1.25	61.0	40.0	1.64	50	71	3 (32, 33)	Strong
140516A	0.19	8.5	6.7	1.87	75	31	3 (18, 31)	Weak
090305A	0.40	52.4	64.0	0.86	50	97	1 (39, 69)	Weak
140129B	1.36	47.6	28.0	2.23	100	14	3 (33, 53)	None
110112A	0.50	14.6	6.7	2.14	87	135	1 (45, 66)	None
090815C	0.60	28.0	16.0	0.90	76	116	1 (43, 86)	None

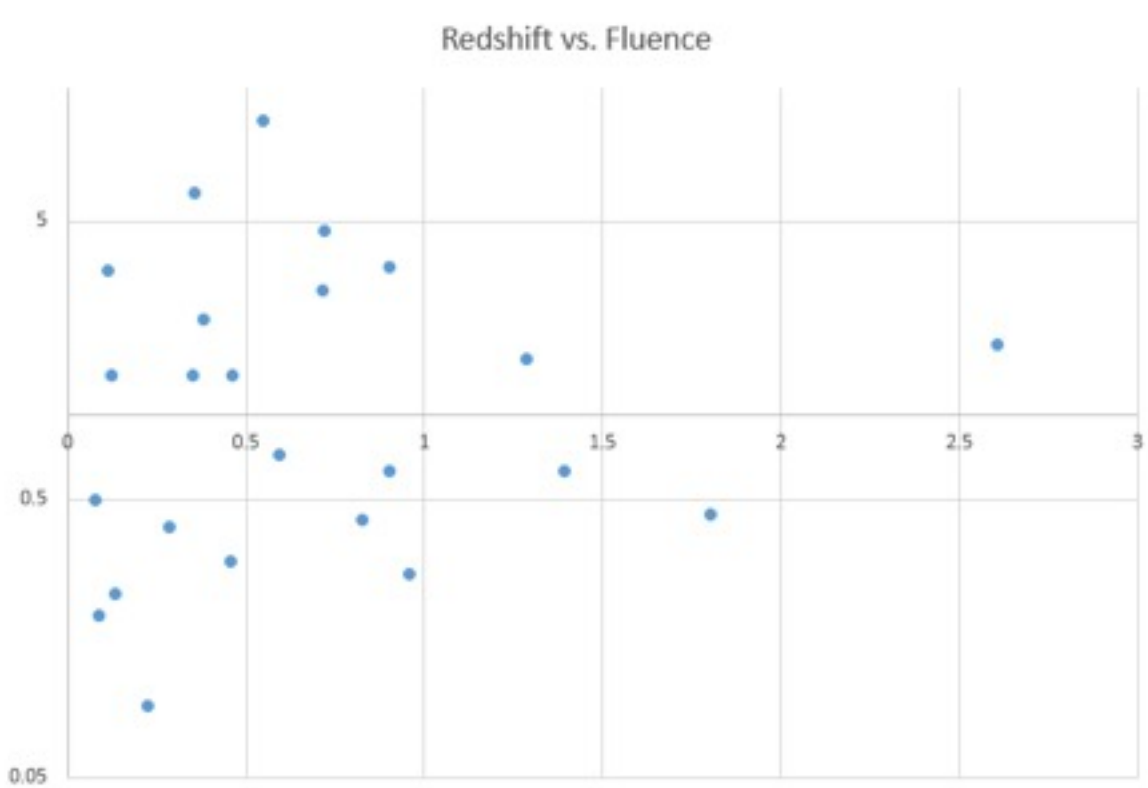
Recovered in untriggered CTTE or CTIME search

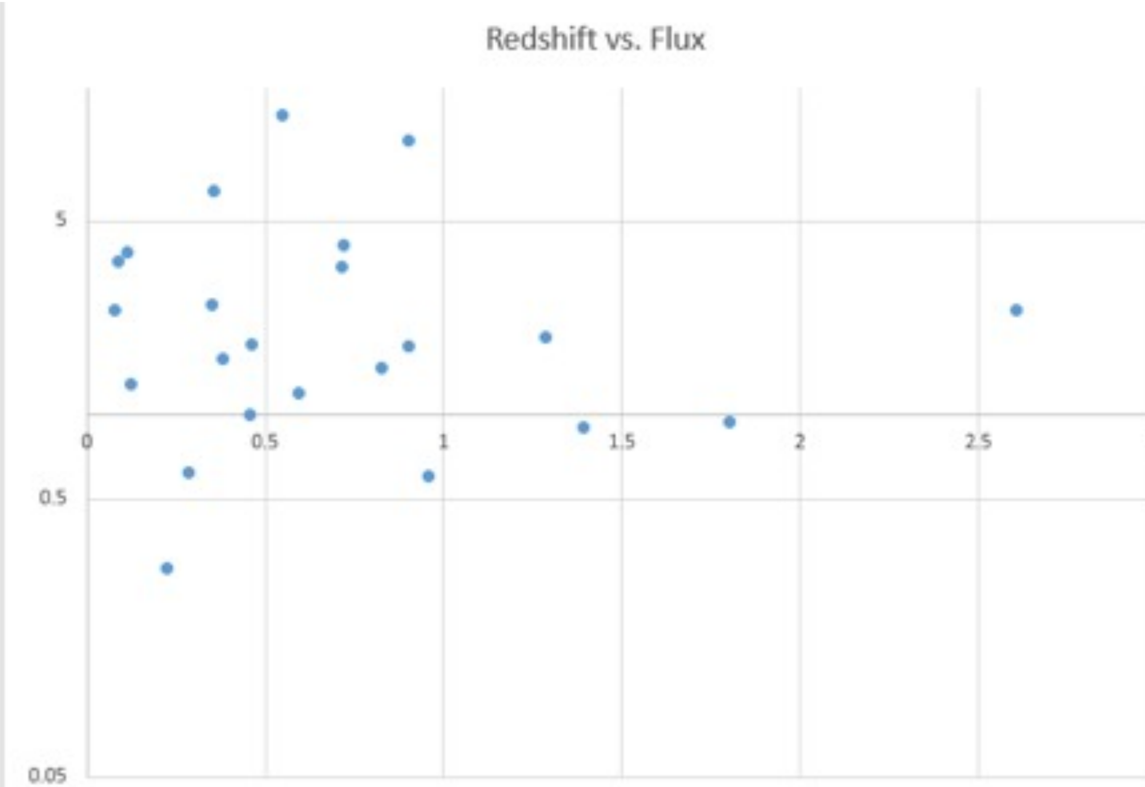
Pre-date availablity of CTTE - not found in CTIME

dbod - can be
d in <50 keV
a, v. soft, not
like GRB

- GBM GRBs Swift BAT misses can also generally be found in ground search.
- Finding weaker short GRBs when search seeded by other instrument motivate blind search
- We expect 2x more short GRBs through this untriggered search: quality control in progress.

Weak short GRBs are not necessarily more distant than bright short GRBs and may lie within the detection horizon of LIGO/Virgo.





Extrapolating from sGRBs with known redshift gives <0.1 - 5 within LIGO horizon (nearby z uncertain)
This number is doubled with unseeded untriggered search.

The significance of sub-threshold LIGO candidates is strengthened with a coincident gamma-ray signal

- Joint GBM-subthreshold search developed for LIGO science runs in 2009 (L. Blackburn et al. ApJ 2014) - no candidates found but GBM background characterized and likelihood-based search finds known short GRBs in GBM data.

- Sensitivity of LIGO search can be improved by x% relative to LIGO alone

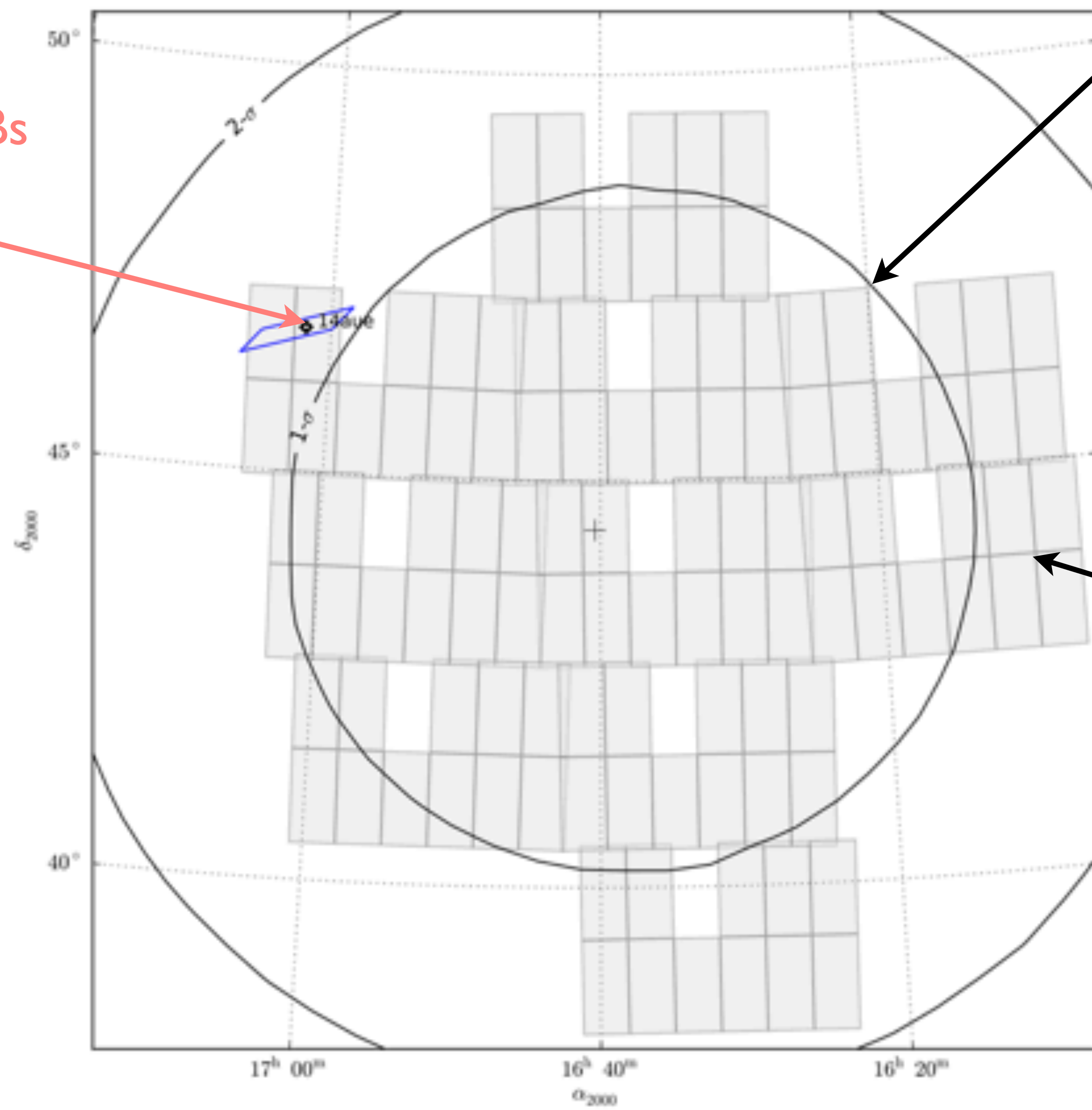
- The GBM-LIGO team has grown, Lindy Blackburn, Michael S. Briggs, Eric Burns, Jordan Camp, Nelson Christensen, Valerie Connaughton, Tito del Canto, Adam Goldstein, Peter Jenke, Tyson Littenberg, Judith Racusin, Peter Shawhan, Leo Singer, Colleen Wilson-Hodge, Binbin Zhang, pipelines have evolved and the search is up and running for LIGO O1:

- Details in poster by Lindy Blackburn

Tiling of GBM localization error regions can be done!

GRB 140508A

One of 8 confirmed afterglows of GBM GRBs by iPTF



The GBM team has characterized localization uncertainties (VC+ ApJS + Poster x by R. Hamburg)

We distribute probability maps to aid follow-up observers

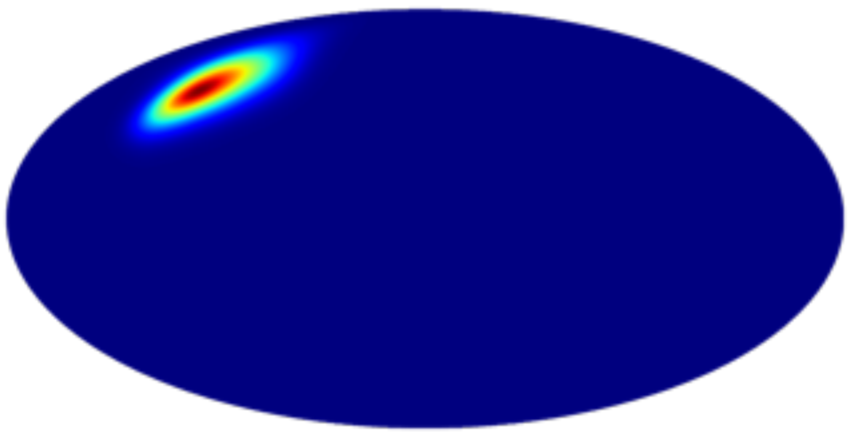
iPTF tiles as much of uncertainty region as possible. 8/40 successes, reported in L. Singer et al. ApJ

No success with short GRBs - upgrade to ZTF with 8 deg FoV

- RECENT! Improved ground-automated localization using more data/smarter algorithm
- NEW! Short/Long flag in GCN notice
- IMMINENT! Probability contours with automated ground locations within seconds
- VERY SOON! Replacement of human-in-loop ~1 hr pos-trigger with automated, 10 min after trigg

Even a large banana and a large orange can help: using joint GBM-LIGO detections and GBM non-detection to guide follow-up observers

Typical GBM GRB localization region for weak GRB



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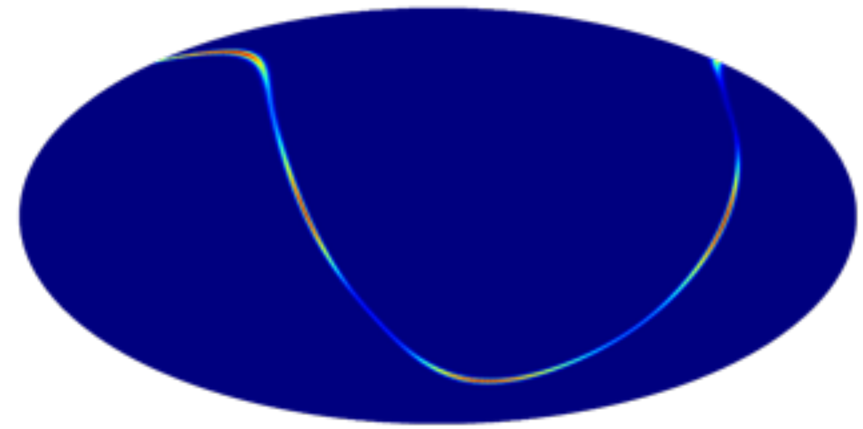
Typical LIGO localization region from http://www.ligo.org/scientists/first2years/



18 +/- 5 nearby galaxies (N. Gehrels et al. 2015)

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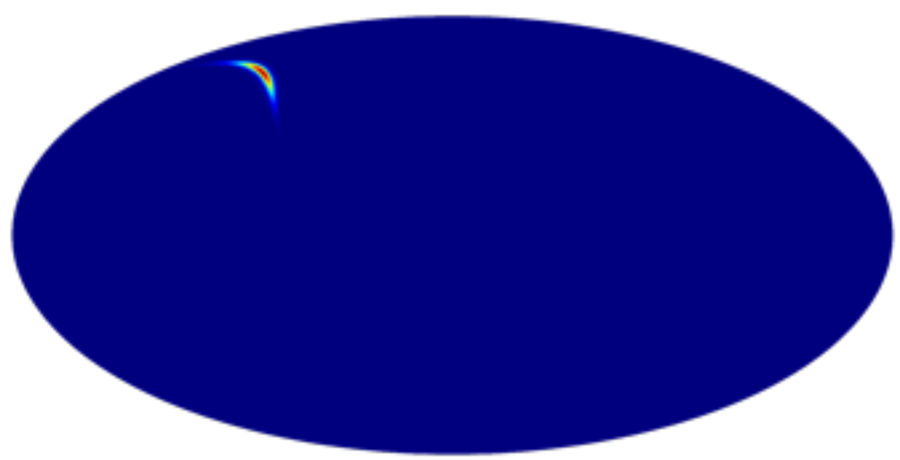

Typical reduction of 80% in sky region:

4 nearby galaxies: easier to follow up with XRT or optical telescopes.

- The non-detection of a GRB (triggered or untriggered) by GBM can limit the sky region to be scann by about 50%, assuming the only e/m signal will be afterglow for on-axis GW candidate.

- Taken from E. Burns at Swift meeting (and in prep) http://www.clemson.edu/ces/physics-astro/conferences/Swift2015

GBM can contribute in many ways to the breakthrough observations of gravitational wave radiation

- A detection by GBM of a short GRB in coincidence with LIGO strengthens the significance of the GW detection
- Sub-threshold searches of GBM data for short GRBs may yield twice as many short GRBs within the LIGO horizon
- Swift BAT can find and localize on the ground GBM GRBs, facilitating follow ups.
- Observing GBM localization regions of 10s sq degs has been successful!
- Joint GBM-LIGO sub-threshold searches can find candidates that would otherwise go undetected
- GBM localization regions can greatly reduce (by 80%) the region of sky to be observed at lower energies
- The non-detection of GBM short GRBs can similarly limit the follow-up region for on-axis merger afterglows.

- Next Huntsville GRB workshop: 24 - 28 October 2016, in Huntsville AL. Details soon!